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Polyvinyl Acetate Lattices as Adhesives for Pigment-Coated Paper

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POLYVINYL ACETATE LATICES
AS ADHESIVES
FOR PIGMENT-COATED PAPER/

Thesis
Submitted to the Faculty
Department of Paper Technology
School of Applied Arts and Sciences
Western Michigan University

in Partial Fulfillment of the Requirement for
the Degree of Bachelor of Science

by
Robert L. Harney

June, 1958

Polyvinyl Acetate Latices As Adhesives
For Pigment-Coated Paper

Table Of Contents

	Page
I. Abstract	1
II. Literature Survey	2
Introduction	2
Review of Coating Terminology	3
Polyvinyl Acetate Latex and Its Components	6
Polyvinyl Acetate as Pigment Binder	10
Literature Cited	15
III. Experimental Design	17
IV. Experimental Work	19
Sequence of Operations	19
Methods and Equipment Used	20
Presentation of Results	23
Discussion of Results	28
V. Conclusions	30

Polyvinyl Acetate Latices As Adhesives
For Pigment-Coated Paper

I. ABSTRACT

Six polyvinyl acetate latices were used in formulations of coating colors by substituting 35 percent of the casein used in a control formulation by latex solids.

Five of the latices contained vinyl acetate copolymers of different monomer composition and ratio as well as of different particle size. The additional latex contained only straight polyvinyl acetate. The control formulation consisted of 100 parts of coating clay and 18 parts of casein, dissolved with the aid of sodium hydroxide.

All latex formulations produced coatings which were superior to the straight casein coating as to brightness, opacity, and gloss. The outcome of tests for other characteristics varied depending on monomers used for polymerization and particle size.

Polyvinyl Acetate Latices As Adhesives
For Pigment-Coated Paper

II. LITERATURE SURVEY

Introduction.

In recent years, the possibility of using synthetic latices as adhesives in the paper coating industry has caused much interest. The manufacturers of latices uncovered a new market by fostering developmental research in the field of pigment coating binders. Polyvinyl acetate latices were one of the group of products studied in this manner.

In the past, experts in the field of coating believed that synthetic latices could contribute substantial improvements to some optical properties of coated papers over and above that of conventional adhesives. It was also felt that synthetic latices could exhibit higher pigment binding power than conventional adhesives.

Recently, Hsia⁽¹⁾ found that polyvinyl acetate latex produced significant improvements of optical properties of coated papers over and above those of conventional casein based coatings. However, the pigment binding power of casein was found to higher than that of the polyvinyl acetate latex used by Hsia. The purpose of this study was to explore further, the significant results of Hsia's investigation.

Review of Coating Terminology.

The following technical terms and phrases, used in the discussion of the art of pigment coating, should be defined in the interest of thorough clarification.

Pigment-coated paper. A pigment-coated paper is a layer of cellulose fibers whose native structural and optical properties have been modified for a specific end use by surface application of coating color.

Coating color. A coating color is essentially a dispersion of pigment plus adhesive in water. Coating colors are divided into two classes according to the method of application; conversion coating colors having mostly 30 to 50 percent solids and machine coating colors having in general, 55 to 70 percent solids.⁽²⁾ Table I contains a typical commercial formulation for a machine coating color.

Table I. A Typical Formulation For An On Machine Coating Color.⁽³⁾

Component	Quantity
Water	520 lb
Sodium metaphosphate	8 lb
Soda ash	2 lb
Calcium carbonate	400 lb
Clay	1600 lb
Oxidized starch dispersion	1280 lb
Pine oil	1 quart
Soap solution, (10 %)	10 gal.
Total solids content	60 %

Pigment. A pigment is a natural or synthetic, organic or inorganic, water insoluble substance with the capacity to modify the optical properties of a sheet of paper. Clay is an example of a natural, inorganic pigment. Titanium dioxide, and precipitated calcium carbonate are examples of synthetic, inorganic pigments.

Adhesive or binder. An adhesive or binder is a highly polymerized chain molecule, generally. Natural or synthetic in origin, an adhesive has the property of bonding pigment particles to the paper fibers and to themselves. Table II shows some examples of natural and synthetic high polymers that are used as adhesives commercially.

Table II. High Polymers Used As Adhesives.	
Compound	Origin
Starch	natural
Casein	natural
Soybean-protein	natural
Glue	natural
Polystyrene-butadiene	synthetic
Acrylonitrile-butadiene	synthetic
Acrylates	synthetic
Polyvinyl acetate	synthetic

Past investigators attribute the adhesive nature of highly polymerized substances to various factors. Koller^(1,4)

believes that the unabsorbed portion of the chain molecule, projecting from the absorbed layer, transfers forces into the adhesive layer when exposed to tensile or shear stress.

Douglas^(1,5) states that adhesion of high polymers to cellulose is a function of several variables: (1) the tack temperature, dielectric constants of the polymer and dipole moments of polymer polar substituents, (2) the nature of the polar groups within the polymer and the modified cellulose, and (3) the close relationship of the adhesion temperature to the adsorption and cohesive energy.

A good coating adhesive meets certain requirements. Casey^(1,6) states that a useful coating adhesive should possess the following properties: (1) high pigment bonding strength and good color, (2) the correct viscosity for the coating color solids content to be used, (3) colloidal stability, (4) a fine balance between filming tendency and plasticity to avoid excess penetration or dust formation upon calendering, and (5) the property of not affecting adversely the surface printability or the pigment hiding power.

Latex emulsions. A latex is a colloidal dispersion of rubber or rubber-like particles in water. A latex emulsion is an intimate mixture of two immiscible substances, one of them, the latex, in the form of fine particles dispersed in the other. Latex-water emulsions are used in paper coating colors as adhesives. However, this type of adhesive is just beginning to play a significant role in coating technology.

Some commercial latices, synthetic in origin and used as adhesives are: polystyrene-butadiene, acrylonitrile-butadiene, acrylates, polyvinyl acetate and copolymer latices of vinyl acetate with other suitable monomers.

The latex particle size exerts an important influence on the characteristics of the latex emulsion. The latex stability is affected by particle size. There is a great increase in hydrophobic surface area as the average particle size is reduced. The stability of the heterogeneous system requires a protective agent for this surface. Such protective agents are called surface active emulsifiers.

Surface active emulsifiers are used in emulsion polymerization and dispersion processes to prevent agglomeration or coagulation of polymer particles, maintaining the hydrophobic surface by electrically charged ions. By varying the amount of surface active agent in the latex, the stability can be controlled.

Polyvinyl Acetate Latex and Its Components

Since polyvinyl acetate latex will be the principal adhesive investigated and evaluated in this study, some information concerning the physical and chemical nature of polyvinyl acetate latex and its components is offered.

Vinyl acetate. The basic substance used in the preparation of polyvinyl acetate latex is vinyl acetate. Vinyl acetate is a colorless liquid having a characteristic sweet odor and is formed as shown in the following chemical equation:



The important physical and chemical properties of vinyl acetate are shown in Table III.

Table III. Some Physical And Chemical Properties Of Vinyl Acetate Monomer. (7)	
Boiling point	72.5° C.
Freezing point	-100.0° C.
Specific gravity	0.9342
Refractive index, n_D^{20}	1.3956
Viscosity at 20° C.	0.432 cp.
Solubility of water in vinyl acetate	0.1%
Solubility in water at 20° C.	2.4%
Ease of polymerization	up to 900 D.P.

There are two general methods by which vinyl acetate is manufactured, the vapor-phase method and the liquid-phase method. Klätte is reported to have synthesized vinyl acetate by the liquid-phase method. (7,8) Liquid acetic acid was reacted with acetylene gas in the presence of mercuric sulfate, the catalyst. The reaction temperature ranged from 60 to 100 C under a pressure of approximately one atmosphere. An impurity, ethylene diacetate, was formed. Recent improvements such as continuous product removal and high pressure-low temperature

conditions have reduced the diacetate production to a minimum.

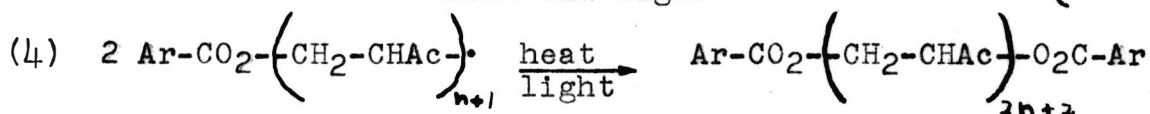
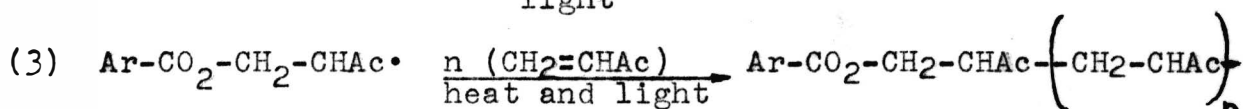
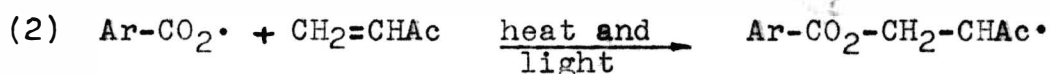
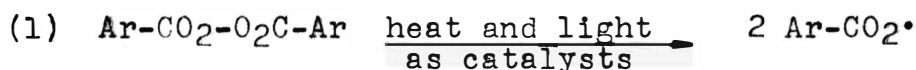
The vapor-phase method has been used commercially in Germany by Alexander Wacker Ges. f. Electrochemische Industrie and Farbwerke Hoechst. (7,9) In this process, acetylene vapor is passed through acetic acid at 120 C, the final vapor concentration being 16.6 percent acetic acid. After preheating to 180 C, the vapor is passed over zinc acetate impregnated charcoal catalysts in iron tubes where the reaction temperature is maintained at 220 C. A yield of 30 percent conversion of acetic acid per cycle has been reported. Other contact catalysts which have been used successfully are: zinc acetate on alumina, zinc acetate on coal, zinc and cadmium silicates, and zinc salts. (7)

Polyvinyl acetate. The next step in the production of polyvinyl acetate latex is the polymerization of vinyl acetate monomer. Polyvinyl acetate is a colorless, odorless, tasteless, and nontoxic thermoplastic resin. The physical properties of polyvinyl acetate can be seen in Table IV.

Table IV. Physical Properties Of Polyvinyl Acetate. (7)

Degree of polymerization, maximum	900
Index of refraction, n_D^{20}	1.467
Density, g./ml., at 20° C.	1.19
Water absorption at 25° C., after 24 hrs.	3.0%
Specific heat, cal./gram	0.389
Tensile strength, maximum	5000 psi
Softening temperature	35° C.
Decomposition temperature	250° C.

Polyvinyl acetate is prepared by the addition polymerization of vinyl acetate monomer. The polymerization reaction is initiated, propagated, and terminated by a free radical mechanism in which a catalyst such as benzoyl peroxide serves as the initiator. The following chemical reactions serve to illustrate the free radical mechanism where $\text{Ar-CO}_2\text{-O}_2\text{C-Ar}$ represents the formula for benzoyl peroxide and $\text{CH}_2=\text{CHAc}$, the formula for vinyl acetate. (10)



Three methods are used to polymerize vinyl acetate commercially. Bulk polymerization is the process in which pure monomer is reacted with catalyst, heat, and light. In solution polymerization, the monomer is dissolved in an organic solvent along with an oil soluble catalyst and then is polymerized. In emulsion polymerization, a heterogeneous system composed of water, monomer, catalyst, emulsifier, and acidity and reduction-oxidation controlling agents is reacted. Among the advantages claimed for emulsion polymerization are: better uniformity of product, better control of particle size and of application in processes.

Polyvinyl acetate latex. The result of the emulsion polymerization of vinyl acetate is a synthetic latex. As stated, polyvinyl acetate latices may either be produced by polymerization of the monomer vinyl acetate or by copolymerization of the monomer vinyl acetate with other suitable monomers such as vinyl stearate, vinyl-2-ethyl hexoate, or ethyl acrylate.⁽¹¹⁾ Table V on the following page, shows the trade names and manufacturers of some commercially available vinyl acetate latices. Information on average particle size, chemical composition, and solids content are also given.

Polyvinyl acetate in the paper industry. Many uses have been found for polyvinyl acetate in the paper industry. Its flexibility and adhesiveness have contributed greatly to its use as a heat sealing agent in solvent coatings. Its high water and oil resistance has been utilized in greaseproof coatings. Polyvinyl acetate has been used in hot melt applications and is now trying to find its place in pigment coating.^(12,13)

Polyvinyl Acetate As Pigment Binder

In the past, there has been little published on the matter of polyvinyl acetate latex as a pigment coating adhesive. However, among the more recent investigations were the work of Hsia, Shapiro, and Argana.^(1,14,15)

Table V. Some Commercially Available Polyvinyl Acetate And Vinyl

Identification Of Latex	Manufacturer	Particle Size, In Microns	
		Range	Mean
Resyn 25-2203	National Starch Co.	—	0.08
Acetex 2700	Naugatuck Chemical Div., U.S. Rubber Co.	—	0.2
Acetex L-3965 (Lotol L-3965)	Naugatuck Chemical Div. U.S. Rubber Co.	—	1.5
VS-VAc Latex Lot No. C-176 Exp. No. 1070-171	Air Reduction Co. Inc. Research And Engineering Dept.	0.5-175	0.75
VS-VAc Latex Lot No. C.-178 Exp. No. 1070-173	Air Reduction Co. Inc. Research And Engineering Dept.	0.5-175	0.75
Vynylite W-130	Bakelite Corp. Unit Of Union Carbide And Carbon Corp.	1.0-3.0	—
"Elvacet" 81-900	E.I. du Pont de Nemours & Co. Electrochemicals Dept.	1.0-3.0	3.0
"Elvacet" 80-900	E.I. du Pont de Nemours & Co. Electrochemicals Dept.	1.0-3.0	3.0
"Elvacet" 84-1100	E.I. du Pont de Nemours & Co. Electrochemicals Dept.	1.0-3.0	3.0
"Elchem" 1440	E.I. du Pont de Nemours & Co. Electrochemicals Dept.	0.3-0.5	—
"Elchem" 1423	E.I. du Pont de Nemours & Co. Electrochemicals Dept.	0.3-0.5	—

Acetate Copolymer Latices

Chemical Composition	Percent Solids	Reference
Vinyl Acrylic Latex	43%	(16)
Vinyl Acetate Copolymer	55%	(17)
Vinyl Acetate Copolymer (Slightly Modified)	55.4%	(17)
Vinyl Acetate-Vinyl Stearate Copolymer, 7.5% Vinyl Stearate On Weight Of Total Monomer	51.6%	(18)
Vinyl Acetate-Vinyl Stearate Copolymer, 15% Vinyl Stearate On Weight Of Total Monomer	51.6%	(18)
Vinyl Acetate Latex	59.6%	(19)
Vinyl Acetate Latex	55-57%	(20)
Vinyl Acetate Latex (Lower Degree Of Polymerization)	55-57%	(20)
Vinyl Acetate Latex	55-57%	(20)
Vinyl Acetate Latex	55%	(20)
Vinyl Acetate Copolymer Latex	55%	(20)

Hsia's investigation. Hsia reported that polyvinyl acetate latex based coatings were low in pigment bonding strength but unusually promising in optical properties as compared to a standard, casein based coating. The polyvinyl acetate latex used by Hsia had a solids content of 59.6 percent, a pH of 4.5 to 5.0 and an average particle size of less than one micron.

In his coating color formulae Hsia started with straight casein as the adhesive and substituted increasing percentages of casein, namely 25, 50, and 75 percent of casein by synthetic adhesives.

Shapiro's investigation. Shapiro reported in his investigation that use of polyvinyl acetate emulsion, "Polyco" 117-55 as a synthetic adhesive resulted in a significant increase in pigment binding power. Data on typical polyvinyl acetate resin emulsions as cited by Shapiro can be seen in Table VI.

Table VI. Typical PVAc Emulsions Reported By Shapiro. (14)

Emulsion classification	Solids	pH	Viscosity (25°C.)	Particle size
Large particle, nonionic	55%	4.0- 4.5	9-20 poises	2-10 microns
Fine particle, nonionic	55%	4.0- 4.5	10-15 poises	1-5 microns
Fine particle, anionic	55%	4.3- 4.6	10-15 poises	0.5-2.0 microns

Argana's investigation. Argana reported the development of satisfactory on-machine greaseproof coatings based on poly-

vinyl acetate emulsions. It was found that use of calcium carbonate as pigment resulted in improved brightness, low coating viscosity, and no adverse effect on grease resistance. Further improvement in brightness resulted from partial replacement of calcium carbonate with rutile titanium dioxide by five to ten percent. Workable coating viscosity and good grease resistance were also maintained in the latter pigment addition.⁽¹⁵⁾ Table VII shows the color formulation proposed by Argana in his pigmentation study. Argana also proposed formulations for greaseproof coatings which are shown in Table VIII on the following page.

Component	Parts by weight
Polyvinyl acetate	100
Plasticizer	8.25
Pigment	132.5
Wetting agent	0.21
Polyvinyl alcohol	3.0
Defoamer	1.0
Water	90.0
Total solids	60%

Table VIII. Greaseproof Coating Formulations. (15)

Component	"Flatboard"	"Flexible board"
"Elvacet" 81-900, PVAc. (55-57% solids)	100 parts	100 parts
"Santicizer" 141 plasticizer	8.25	13.75
"York" whiting no.7 (CaCO ₃)	119.25	96.75
Rutile Titanium dioxide	13.25	10.75
"Tamol" 731 (25% aq. sol.)	2.1	1.8
"Elvanol" 71-30 PVA. (10% sol.)	30.0	30.0
"Polyglycol" P-1200	1.0	1.0
Water	34.0	34.0
Properties:		
Total solids	65%	65%
Viscosity (26°C.) cp.	1600	2700
Pigment to binder ratio	2:1	1.5:1
PVAc. resin to PVA. resin	18:1	18:1
PVAc. resin to plasticizer	6.6:1	4:1

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III. EXPERIMENTAL DESIGN

In order to compare the performance of aqueous vinyl dispersions, six sets of coatings, containing different commercial grades of polyvinyl acetate and polyvinyl acetate copolymer latices as part of the adhesive, were to be formulated, applied to coating raw stock and evaluated in comparison with a set of control coatings containing straight casein as the adhesive. The coatings were to be evaluated by measurement of their optical properties and their pigment bonding characteristics. The coating formula to be used would be composed as shown in Table IX.

Component	Coating color I (control)	Coating colors II-VII
Coating clay	400.0 grams (A.D.)	400.0 grams (A.D.)
Casein	72.0	46.8
Latex (dry basis)	none	25.2
Hexamine	2.88	1.87
Sodium hydroxide	2.88	1.87
Dowicide "G"	2.88	1.87
Distilled water	650.0	646.2
Percent solids	42.5%	42.5%

Argentina casein and predispersed coating clay were to be used. Hexamine was employed to insolubilize the casein. Sodium hydroxide was to be used to cut the casein. Dowicide G was to be added to preserve the casein. All water used in preparing the coating dispersions was to be distilled water. Table X shows the important properties of the polyvinyl acetate and vinyl acetate copolymer latices that were to be used.

Table X. The Important Properties Of The Latices To Be Used				
Number Of Coating Color	Trade Name Of Latex	Particle Size (Ave.)	Percent Solids	Chemical Composition
II	Lotol L-3965	1.5 microns	55.37%	Vinyl Acetate Copolymer
III	Acetex 2700	0.2	56.31	Vinyl Acetate Copolymer
IV	VS-VAc C-178	0.75	51.6	Vinyl Acetate Copolymer, 15 Percent Vinyl Stearate On Weight Of Total Monomer
V	Resyn 25-2203	0.08	43.0	Vinyl Acrylic Resin Copolymer
VI	Vinylite W-130	2.0	59.6	Vinyl Acetate Polymer
VII	VS-VAc C-176	0.75	51.6	Vinyl Acetate Copolymer, 7.7 Percent Vinyl Stearate On Weight Of Total Monomer

IV. EXPERIMENTAL WORK

Sequence of Operations.

The following steps of operation were planned to put the experimental design in effect:

(1) Prepare coating color (using coating formulations indicated in Table IX).

(2) Adjust coating viscosity to 350 centipoises plus or minus 50 Brookfield viscosity at 80 F using number two spindle at 100 revolutions per minute.

(3) Adjust pH to 8.5 plus or minus 0.5 with ammonium hydroxide.

(4) Determine solids content, remain as close as possible to 42.5 percent.

(5) Use standard coating raw stock, basis weight 50.3 pounds (25x38-500), and apply coating to weight 14 plus or minus 1.5 pounds.

(6) Use draw down method, coat on wire side only on nine by twelve inch sheets by means of wire wound R.D. rods.

(7) Dry sheets at 200 F for four minutes by air drying, avoiding contact with metal surfaces.

(8) Cut sheets to seven by nine inches, determine proper weight range, and condition at least two hours at 73 F and 50 percent relative humidity.

(9) Supercalender with three passes, at 20 pounds gage pressure at 85-90 F, and condition sheets one

week at 73 F and 50 percent relative humidity.

(10) Evaluate the sheets as to brightness, opacity, gloss, smoothness, Dennison Wax pick, and I. G. T. dynamic pick.

Methods and Equipment Used.

Preparation of Coating Color.

Preparation of the clay slip. The coating clay was first converted into a clay slip of 75 percent solids. Two thousand grams of predispersed clay were placed in a Day mixer. With constant agitation, the required amount of distilled water was added slowly. When a slip of uniform texture was produced, the mixture was agitated for 20 more minutes. Two batches were prepared in this manner and stored in two large jars for future use.

Preparation of the adhesive. The casein was dissolved with the aid of caustic soda to yield 20 percent solids. It was preserved with Dovicide G and prepared fresh for each coating color.

Preparation of the control coating mixture. The first step in the preparation of the control coating dispersion was to soak 72.0 grams of dry Argentina casein in 202 grams of distilled water for twenty minutes with constant agitation. A solution of sodium hydroxide was prepared by dissolving 2.88 grams of sodium hydroxide in 54.6 grams of distilled water. The caustic solution was the added to the casein in water.

The combined mixture was weighed and heated on a double boiler with constant stirring at a temperature of 140 F (60 C) for twenty minutes. The alkaline casein solution was cooled and weighed. Water was added to make up for evaporation losses. A solution of 2.88 grams of Dowicide G in 25.85 grams of distilled water was added to the casein solution as preservative.

Clay slurry equivalent to 400 grams of dry clay was placed in a weighed metal beaker. In order to prevent coagulation of the clay slip, the so-called "casein shock", the required quantity of casein was added slowly in small portions under vigorous agitation. Distilled water required to dilute the coating color to 47.0 percent solids was added followed by a solution prepared from 2.88 grams of Hexamine and 10 grams of water as insolubilizer for the casein. The dispersion was then checked for proper pH with a standardized pH meter. Ammonium hydroxide, when required, was used dropwise to adjust the pH level of the coating dispersion.

After the proper pH range of 8.5 had been reached, the coating dispersion was diluted slowly with distilled water and tested for the proper viscosity range. The Brookfield viscosity was to be 350 plus or minus 50 centipoises at 80 F using a number two spindle at 100 revolutions per minute. The coating color was now ready for application to the uncoated sheets.

Preparation of the latex-containing coating dispersions.
The latex-containing coating dispersions were prepared in the same general manner as the control coating except that pro-

portionally smaller quantities of casein, caustic soda, Dowlicide, and Hexamine solutions were required. Also, to prevent coagulation of the latex, it was found advisable to dissolve the casein first, and to use it to stabilize the latex. The casein-latex mixture was added slowly to the required amount of clay slip. The coating color was then adjusted to meet with the desired conditions of pH, viscosity and solids content as was done with the control coating.

Application of Coating and Supercalendering.

The paper was placed wire side up on a nine by twelve inch glass plate. A bead of coating color, applied across the top side, was drawn down with the aid of a wire wound R. D. doctor rod. The sheets were put in an oven, air dried for four minutes at 200 F, and weighed. Only sheets meeting the specifications as to coat weight were accepted.

The accepted coated papers were conditioned at 73 F plus or minus two degrees and at 50 plus or minus two percent relative humidity for at least two hours and supercalendered on a three roll laboratory supercalender at 20 pounds gage pressure and at 85-90 F surface temperature of the rolls. Each sheet was subjected to three passes through the calender.

Testing of Coated Sheets.

After supercalendering, the sheets were again conditioned at 73 plus or minus 2 F and at 50 plus or minus 2 percent relative humidity. Thereafter, they were tested by the following methods:

Brightness. The brightness values of the supercalend-
ered coated sheets were obtained by using a Photovolt Bright-
ness Tester.

Gloss. The gloss values of the paper were determined by
means of Photovolt Gloss Tester.

Opacity. This property was determined by use of a Bausch
and Lomb Opacimeter in compliance with T-425m.

Smoothness. Smoothness values were obtained by means of
a Bekk Smoothness Tester as is specified in TAPPI Standard
Method, T-479m.

Pigment bonding strength. Two methods were used to eval-
uate the pigment bonding strength of the coatings, a static
method and a dynamic method. The Dennison Wax test, the stat-
ic method, was carried out in accordance with T-459m. The
dynamic method used was the I.G.T. print and pick test. Val-
ues were obtained with a number four tack black ink and the
apparatus was loaded at 35 kilograms tension.

Presentation of Results

Data on the coating colors used may be seen in Table II.
The results of testing the coated, supercalendered paper are
presented in Tables XII and XIII. These results are shown
in form of bar graphs on pages

Table XI. Properties Of Coated Colors Used

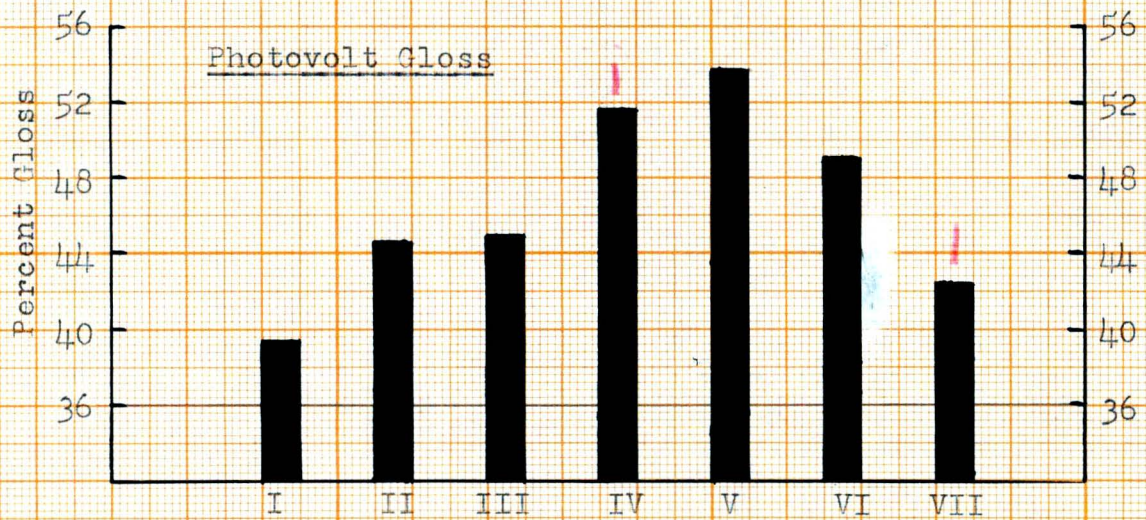
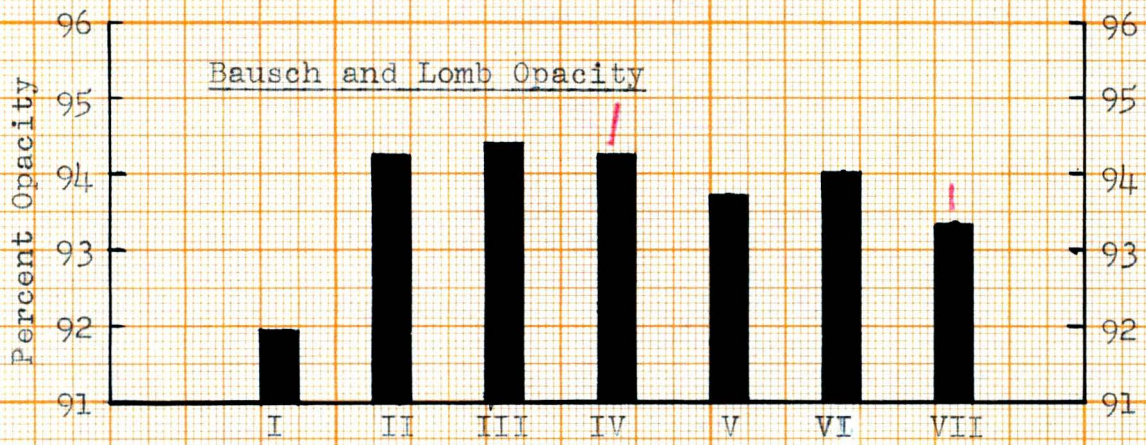
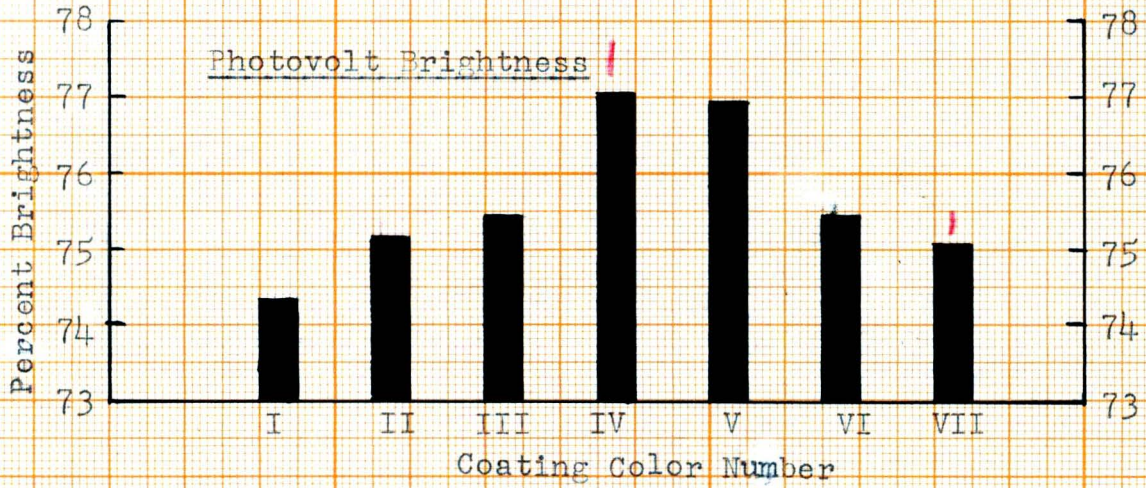
No.	Adhesive Used	pH	Solids Content Percent	Brookfield Viscosity Centipoises	Latex Particle Size, Microns	R.D. Rod No. Used
I	100% Casein	8.20	38.60	340		15
II	65% Casein 35% Lotol-L-3965	8.50	43.59	348	1.5	13
III	65% Casein 35% Acetex 2700	8.50	41.66	357	0.2	13
IV	65% Casein 35% VS-VAc C-178	8.38	43.85	335	0.75	13
V	65% Casein 35% Resyn-25-2203	8.45	42.50	361	0.08	13
VI	65% Casein 35% Vinylite W-130	8.40	42.30	360	1-3	13
VII	65% Casein 35% VS-VAc C-176	8.58	41.19	365	0.75	13

Note: Brookfield viscosity taken at 80 F with no. 2 spindle at 100 rpm and converted to centipoises.

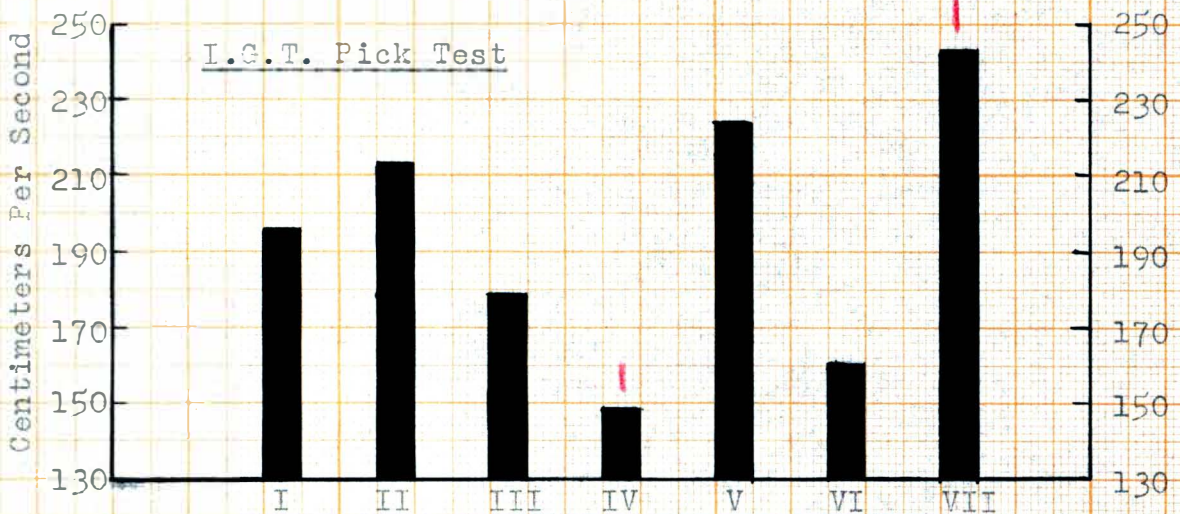
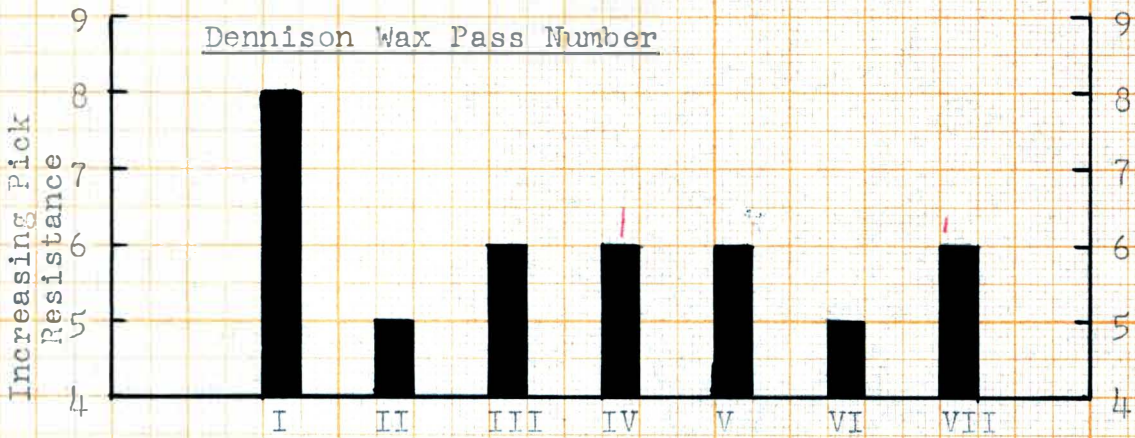
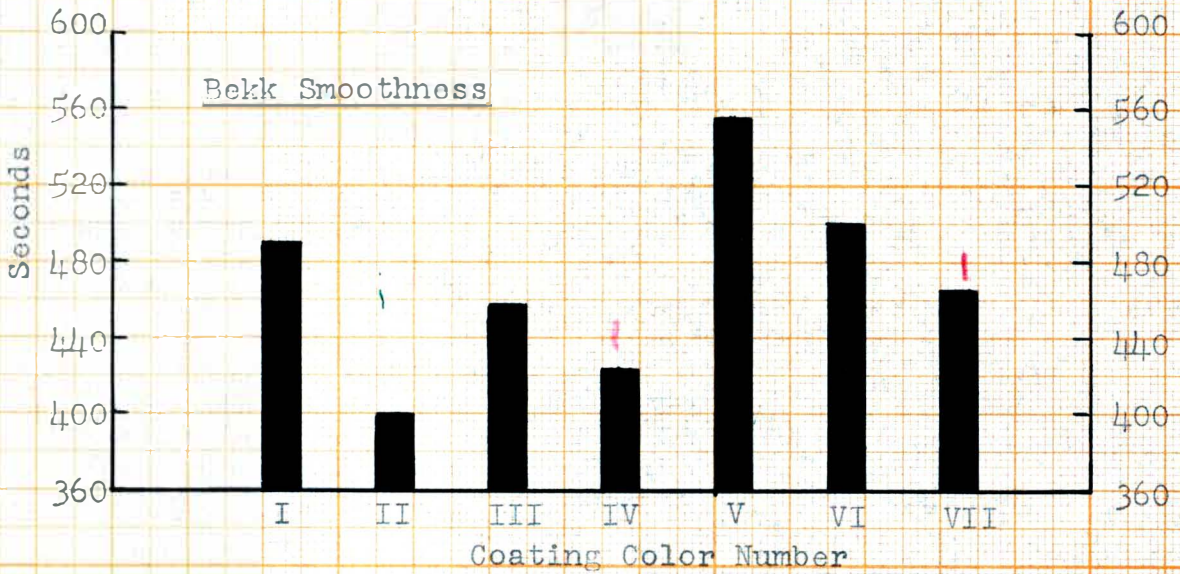
Table XII. Test Results				
No.	Adhesive	Brightness Percent	Opacity Percent	Gloss Percent
I	100% Casein	74.33	91.94	39.51
II	65% Casein 35% Lotol L-3965	75.17	94.25	44.61
III	65% Casein 35% Acetex 2700	75.43	94.39	44.81
IV	65% Casein 35% VS-VAc C-178	77.06	94.24	51.80
V	65% Casein 35% Resyn-25-2203	76.94	93.71	53.92
VI	65% Casein 35% Vinylite W-130	75.44	94.00	49.00
VII	65% Casein 35% VS-VAc C-176	75.08	93.30	42.35

Table XIII. Test Results				
No.	Adhesive	Bekk Smoothness Seconds	Dennison Wax Pass No.	I.G.T. Pick Test Cm/sec
I	100% Casein	490.4	8	196.1
II	65% Casein 35% Lotol L-3965	400.1	5	212.5
III	65% Casein 35% Acetex 2700	457.6	6	178.6
IV	65% Casein 35% VS-VAc C-178	423.7	6	149.3
V	65% Casein 35% Resyn-25-2203	555.6	6	223.8
VI	65% Casein 35% Vinylite W-130	499.8	5	161.4
VII	65% Casein 35% VS-VAc C-176	465.0	6	243.0

RESULTS OF OPACITY, BRIGHTNESS,
AND GLOSS



RESULTS OF SMOOTHNESS, DENNISON WAX,
AND I.G.T. PICK TESTS



Discussion Of Results.

Comparison of Polyvinyl Acetate Latex Formulation With Straight Casein.

The polyvinyl acetate latex coating color formulation, containing latex VI with relatively large particle size, was superior to the straight casein mixture (formula I) as to brightness, opacity, gloss, and smoothness but was inferior in pick resistance as shown by the results of both the Dennison Wax method and the I.G.T. pick test. This is in agreement with the findings of Haia.⁽¹⁾

Comparison of Copolymer Latex Formulations With Straight Casein.

The vinyl acetate copolymer formulations II and III, containing latices of comparable composition but of different particle size, were found to be superior to the straight casein coating color (formula I) in brightness, opacity, and gloss. However, formulae II and III were inferior as to smoothness and Dennison Wax pick test. Coating color II was slightly superior to the straight casein formula as to I.G.T. pick test whereas III was inferior.

The formulations IV and VII, containing vinyl acetate-vinyl stearate latices of the same average particle size, but of different composition as to ratio of the monomers, were superior to the straight casein coating color in brightness, opacity, and gloss. Both formulations were inferior in smoothness, and Dennison Wax pick test. Latex VII, however, was

superior to the straight casein formulation as to I.G.T. pick test whereas formulation IV was inferior.

Latex formulation V, composed of a vinyl acrylic copolymer of extremely small particle size, was found to be superior to the straight casein coating color as to brightness, gloss, opacity, smoothness, and I.G.T. pick while being inferior in Dennison Wax pick.

Comparison of the Latex Formulations Among Each Other.

Brightness. Latex formulations IV and V were found to produce highest brightness, followed by latices III, VI, VII, and II in declining order. All latex formulations produced coatings higher in brightness than the straight casein-pigment coating.

Opacity. Latex formulations III, II, and IV were found to produce highest opacity, followed by latices VI, V, and VII in declining order. All latex formulations produced coatings higher in opacity than the straight casein-pigment coating.

Gloss. Latex formulations V and IV were found to produce highest gloss, followed by latices VI, III, II, and VII in declining order. All latex formulations produced coatings higher in gloss than the straight casein-pigment coating.

Smoothness. Latex formulations V and VI were found to produce highest smoothness, followed by latices VII, III, IV, and II in declining order.

Dennison Wax Pick Test. Latex formulations III, IV, V, and VII were found to produce about the same Dennison Wax

pick resistance; latex formulations II and VI produced slightly lower wax pick resistance than the first four latices of the group.

I.G.T. Pick Test. Latex formulations VII and V were found to produce highest I.G.T. pick resistance, followed by formulations II, III, VI, and IV in declining order.

V. CONCLUSIONS

(1) All latex formulations produced coatings which were superior to the straight casein-pigment coating as to brightness, opacity, and gloss.

(2) Due to the thermoplastic nature of all latices used, the non-thermoplastic casein formulation yielded higher results of the Dennison Wax pick tests than the latex containing coating colors.

(3) Three latex formulations were superior and three lower than straight casein as to the I.G.T. dynamic pick test.

Two copolymer latices of relatively small particle size showed best performance in coatings evaluated by the I.G.T. pick tester, namely a vinyl acetate-vinyl stearate latex and a vinyl acetate-vinyl acrylate latex.

Two other copolymer latices of unknown composition, one of large and one of small particle size, performed in the same range as the straight casein formulation as to results of the I.G.T. pick test.

The remaining two latices, a straight vinyl acetate latex

of large particle size and a copolymer of small particle size gave lower results than found for straight casein formulations.

(4) In overall performance, latex V was found to be the best, followed by latices VII, and II in declining order.

(5) A study of latices II and III showed that a slight improvement in all optical properties of the coating was gained by lowering the ultimate particle size of the latex.

(6) A comparison of the performance of latices IV and VII showed that the vinyl acetate latex copolymerized with the higher quantity of vinyl stearate produced better pigment bonding strength, and smoothness, whereas the latex with the lower quantity of vinyl stearate produced better opacity, brightness, and gloss.

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